Foodgrain Supply Demand Equation in 2050

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FOODGRAIN SUPPLY DEMAND EQUATION IN 2050 : AGENDA AND ISSUES

*R.P. Kapoor**

The initial thoughts of this paper were presented as a valedictory address at an International Seminar orgainsed by the Alumni of National Academy of Agricultural Research Management (NAARM, Hyderabad) on the theme of "Agricultural Research Systems and Management in the 21st Century". The stimulating discussions that followed the address, prompted me to accept the suggestion of the Alumni to put my thoughts in writing and hence this paper.

I

Introduction

Another 12 years and we will enter the 21st century with hopes and aspirations for a life of material comfort with a long life-span of around 75 years. By 2050, India will have turned into a predominantly urban-industrial society with technology revolution spreading at a rapid rate. The annual income may be around $ 3500 per capita and the Indian Society would have become more cohesive, more democratic and more egalitarian. A host of new policies will evolve to shape and facilitate this transition. Eventhough agriculture may account for just about 10 per cent of the total economy, continuing self-sufficiency in agriculture, and more particularly foodgrains production, will be crucial for any future development strategy. The process of transition into a modern society cannot be sustained, and may even abort, if foodgrain supplies fail to match the increasing demand. It is in this context that a continuous review of the foodgrain demand-supply scenario should be the first item on the agenda of any futurology studies. This paper is an attempt in this direction.

Foodgrain demand projections set forth in this paper take into consideration factors like population size of the country in 2050, likely increase in nutrition levels and changes in the consumption pattern resulting from projected increases in per capita income. Based on relevant assumptions, it is projected that foodgrain demand would be of the order of 550 million tonnes per annum by the year 2050. This target is both desirable and feasible. Resource analysis also supports the possibility of reaching this level of production, provided early action is initiated with regard to certain supply

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side issues, which if left unattended to, could become formidable bottlenecks in producing needed quantities of foodgrains and animal products.

Agriculture science and technology research system is well-organised to take advantage of the emerging areas of technology for raising productivity of land per unit of time. However, greater attention needs to be paid to the problems of adaptive research at micro soil-climatic conditions and the examination of the issues relevant to the financial and economic gains to the farmer from the new technology or cropping practices. Supply of inputs and credit, efficient marketing, warehousing and processing of output to match consumer desires are related set of issues for raising productivity. Modernisation and urbanisation go together. As a result of rapid urbanisation, rural population may be reduced to less than 300 million by the middle of the next century, from a level of 650 million by the end of 20th century. This and the related demographic shift will underscore the mechanisation needs and issues. Finally, raising productivity per unit of water used for irrigation will be crucial for determining productivity of agriculture in the next century.

These projections are not forecasts but estimates based on certain set of assumptions and should be viewed as such. These are meant to stimulate discussion and debate. Projections may be refined in the light of new knowledge and greater insights. New research leads and any worthwhile breakthrough in the technology of dryland farming could even alter the present paradigm of farming system. It is, however, prudent to look at the future and take advance action, lest events overtake us.

Futurology of food production : A global view

The story of advancement of civilisation is a story closely related to the search and practice of newer methods of satisfying hunger – the most elementary and basic need of humankind. It is believed that 10,000 years ago mankind started adopting agriculture as a way of life. It is the oldest and the most essential of human pursuits. Nearly 220 years back, countries in Western Europe which were able to satisfy the food needs of the population, either through internal production or imports, triggered the industrial revolutions. This, in turn, affected agricultural production processes and technology. Application of this new science and technology has turned Western Europe into a food surplus zone eventhough agro-climatic conditions are not favourable for round the year crop husbandry. We are now at the threshold of a techno-scientific revolution and this, in turn, will influence the shape of agriculture. Twelve years hence begins the 21st century. It is, therefore, timely to start anticipating the challenge of the 21st century to prepare ourselves for the needed responses. This art and science of looking at a distant future is developing into a discipline by itself. Futurology is both exciting and romantic as well as risky and speculative. Risky because

of the preponderance of uncertainties about the rapidly advancing science and technology horizons, changing societal values and norms, international relations and issues of war and peace. Report of the Club of Rome and the Global 2000 Report[1] caution us how anticipation and projections could be frightening and wrong and still proved useful because these projections evoked immediate deep analyses and hastened the initiation of corrective policies to avoid the frightening prospects. Thus, reflecting and anticipating future, even with varying degree of accuracy or inaccuracy, is a worthwhile effort. It starts a debate on assumptions and projections and forces a more careful evaluation of policy alternatives. A continuing refinement of these projections can give a fair idea of what the future might hold. Human effort can be geared in time to avoid a situation where the events might overtake mankind.

In specific terms agricultural researchers have to help generate technology to augment supplies of agricultural products to meet the demands of the 21st century. In a way, therefore, Demand-Supply Equation of agricultural commodities should define the agenda of research and management systems for the next century. Providing basic food for the population and banishing hunger should be the first item on this agenda. So population size and demography become relevant.

World population today is about 5 billion; It is projected to become 6.1 billion in the year 2000, over 8 billion by 2025 and nearly 10.5 billion by the end of the next century. In simple terms, the basic food production must double to maintain the *status quo*. There is, however, another dimension—20 per cent of the people or nearly one billion live below the poverty line. These are the people who do not get sufficient food for healthy living and active life. The first responsibility of any civilised society is to ensure availability of food for these people. Hunger must be banished from the surface of earth. Some allowance should also be made for increased consumption as a consequence of rising incomes in third world countries and the resulting increase in meat and poultry intake. Therefore, the increased agriculture production should aim not only at doubling but perhaps trebling of foodgrain production in the next century *i.e.*, increasing world foodgrain production from the present level of around 2.8 billion tonnes grain equivalent (tge) to around 7 billion tge a year[2]. This level of production is not beyond the realm of possibility for the world as a whole. However, these global averages mask vide variations.

Growth in foodgrains demand in developed countries of the world is projected to level out. These countries, as a group, are surplus in food and they have almost reached a Zero Population Growth Rate (ZPG) status. Developing world is experiencing High Population Growth Rate (HPG) of over 2 per cent a year. These countries are already food deficit, and the gap between domestic supply and demand is projected to widen. The annual yield of all the cereals in developed market economies may be around 5 ton-

nes per hectare. In contrast, in the developing world (excluding China) it is more likely to be less than 1.5 tonnes per hectare. This wide gap in productivity levels in two sets of countries can be largely explained by three factors which contribute to the developed world's productivity:

Firstly, continuous research and technology development for higher crop production to suit the socio-economic, agro-climatic and soil conditions: mechanisation, chemicalisation and genetic improvement, region-specific technology packages;

Secondly, high degree of capital investment in soil and water management, and land formation; and Thirdly, human resource which readily evaluates and absorbs new technology.

Agriculture production increases in the first half of the 20th century were achieved through increases in croplands. This is no longer a viable option: cropland expansion has slowed down from 1 per cent in 50's to 0.3 per cent in 70's and it is projected to be only 0.15 per cent in 90's. Thus, the limit in regard to availability of additional arable land may be reached by the beginning of the 21st century. The challenge for the research system in the 21st century is to evolve land-productivity-increasing farm technologies suited to the local environmental conditions of diffe-ent agro-climatic regions of developing world. In the first quarter of the 21st century majority of developing countries will continue to be surplus in labour and short in capital. Providing gainful employment in agriculture sector to the rapidly expanding labour force will be a priority policy imperative for stability and peace in these societies. Therefore, the technologies should not be oriented towards high degree of mechanisation. However, introduction of sophisticated farm machinery will become necessary in the next century when rural population starts declining in absolute numbers and the structure of production changes radically with agriculture accounting for 30 or a much lower percentage of the Gross National Product of the present day low income economies. Many researchers have looked at global food situation well beyond the 20th century. Instead of reviewing these findings, it may be a more exciting venture to reflect on the prospectus of agriculture development in India in the 21st century: the challenging increase in foodgrain demand and a bold research management response for augmenting supplies. This issue is discussed in the next section.

II

Foodgrain Demand Projections: 2050

In India's context, agricultural growth will continue to be an important determinant of its overall development process. Producing enough food for the growing numbers had been the mandate for agriculture research and extension in the past, and considering the large number of people who still

go hungry, it would continue to be so in future. However, new areas of concern are emerging with increasingly larger number of people getting higher purchasing power and demanding better quality food. There is likely to be greater demand for fruits, vegetables and animal nutrients. Agriculture research is on the threshold of a new revolution which may have major implications for the future of the country. It certainly offers the best hope for a quick solution of the manifold problems of hunger, poverty and want, which haunt 40 per cent or 260 million of India's rural population.

It is risky to prophecy the future. However, keeping in view the past trends in the country and drawing lessons from the development trends leading to present situations in the advanced world, this paper attempts at anticipating an approximate demand and supply equation of cereals in the 21st century, examines resource constraints and identifies some key research issues.

Population factor. Satisfying basic hunger and nutritional needs of the growing population of the country will be the first important factor in agricultural demand equation. For this purpose, it is necessary to set out, in the very beginning, the assumption regarding India's population which is estimated at around 770 million (mid 1987) and continues to grow at around 2 per cent a year: a birth rate of 32.5 per thousand population, mortality rate of 12.5 and infant mortality rate of around 90 per thousand live births. Trend in fertility decline is clearly noticable.

The Planning Commission has projected that India's population may reach 980 million by 2001. It is further anticipated that the country should reach a net reproduction rate of unity (NRR:1) during the period 2001-2005. The World Bank has also prepared a set of alternate projections for India's population for 21st century.

Table 1 : World Bank projections of India's population size (in millions)

	Assumptions	Pop. Size in 2000	Pop. Size in 2050
1.	Standard fertility mortality decline	994	1513
2.	Rapid fertility decline and standard mortality decline	927	1313
3.	Rapid fertility and mortality decline	938	1406

Source : World Development Report, p. 77.

The assumption of Planning Commission on population size appears to be on the higher side as these are based on the birth rate influencing trend line assumptions of the past 25 years. Birth rates declined from 40 in 1971 to around 34 in 1978. Because of slackness in family planning during 1977-

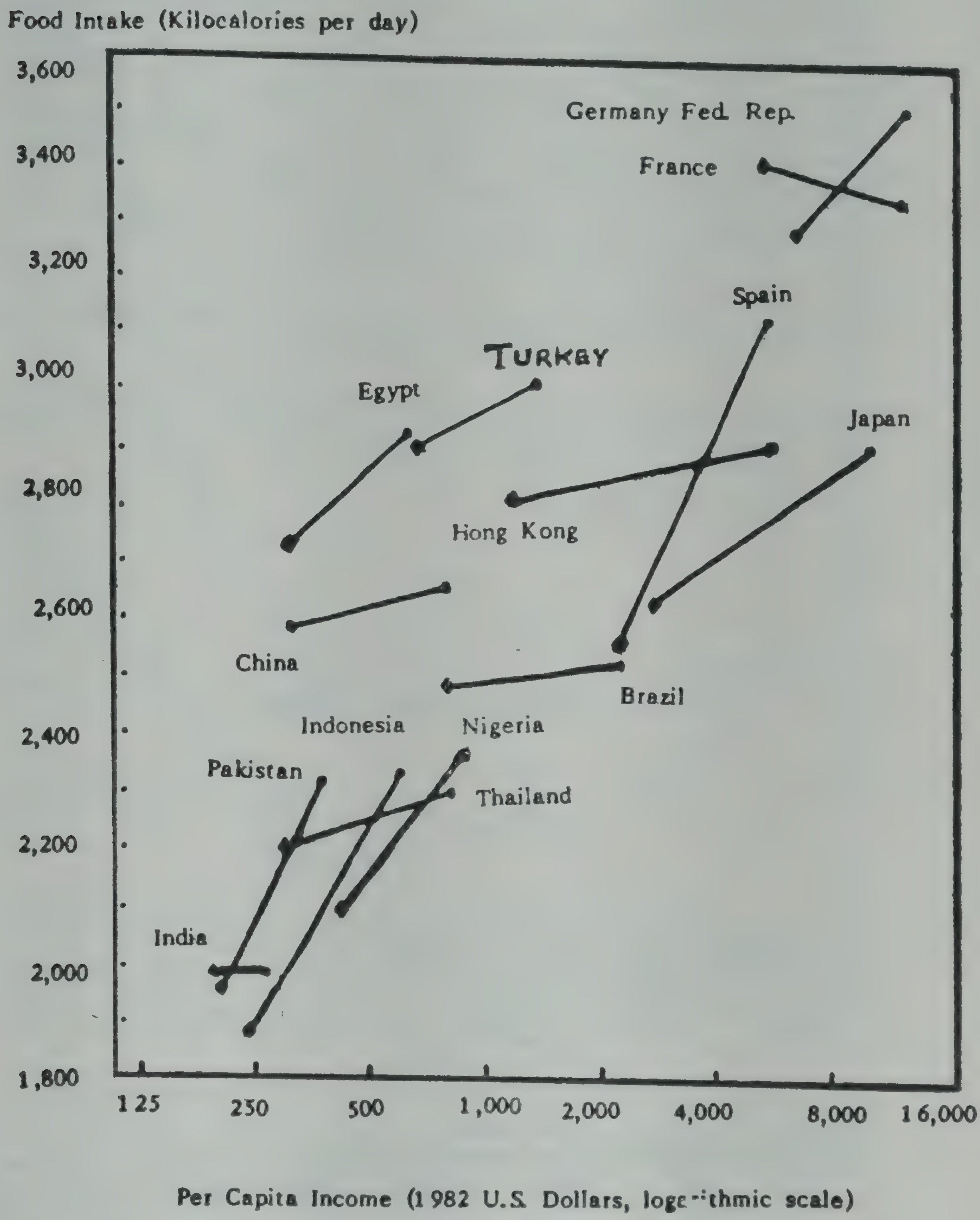
82, birth rates stagnated at around the same level till 1984. However, 1985 and 1986 have witnessed a decline in birth rates of an order of around 0.75 points each year. The birth rate in 1986 is estimated at around 32.5 per thousand population. There is no reason why this declining trend should not continue. Keeping in view the improvement in relevant socio-economic factors which influence the demographic transition, the growing acceptance of small family norm and contraception as a way of life, and the commitment to the programme of health for all by 2000, it is anticipated that World Bank projection of population size related to 'rapid fertility and rapid mortality decline assumption' would be more realistic. This is borne out by the experience of East Asian countries.

The population size assumptions, for working out foodgrain demand projections hereunder are related to a population size of 950 million in 2000 and 1400 million in 2050.

Demand projection for 2000. On a straightline arithmetical basis, requirements at the prevailing consumption pattern and nutrition level, could be projected at 213 million tonnes of foodgrains for the year 2000. These projections are related to food, seed and animal feed per capita daily requirements of 2250 calories. The targeted poverty alleviation programmes and the reduction in the poverty ratio will lead to an increase in average per capita daily nutritional needs. Similarly, raising incomes will change the pattern of consumption in favour of animal proteins and consequently greater foodgrain requirements. The combined effect of these two developments may result in a 10 per cent increase in the daily nutrition requirements or nearly 2500 calories per day. To match these consumption requirements, the foodgrain production should be of the order of 234-238 million tonnes by the year 2000. This estimate is very close to the 240 million tonnes projection, put forth in the macro-dimension perspective of the Seventh Plan by the Planning Commission (Vol.1 p.15).

2050 : *Changing Food Intake Pattern And Projected Demand.* Based on the increase in the population size from 950 mill on at the turn of century to 1400 million in 2050, at a level of 2250 calories per capita daily food intake, foodgrain demand could be estimated at about 350 million tonnes per year. However, by the year 2050 per capita income may easily reach a level of $ 3500 per annum: a near 14-fold increase compared to the present per capita income of $ 260, or an 8-fold increase compared to $ 425 income level projected for the year 2000 (Appendix). This increase in income levels will affect foodgrain requirements in two ways: firstly, daily intake of food will increase, and secondly, it will bring about a definite change in the food consumption pattern. Animal products, including poultry, will form a much higher percentage of food intake of the population. A World Bank study has explored the relationship between per capita income and daily caloric intake of food, as also the relation between per capita income and share of animal products[3]. Food intake and share of animal products rise

Per Capita Food Intake in China, 1981-2000, and Other Selected Economies 1960-80.



- Relationship in about 1960
- Relationship in about 1980
- QUADRUPLE projection 2000

Source : China, Long Term Development Issues and Options, A World Bank Country Economic Report, pp. 51 & 52.

Share of Animal Products in Total Food Intake in China, 1980 - 2000, and in Other Selected Economies, 1960-80.

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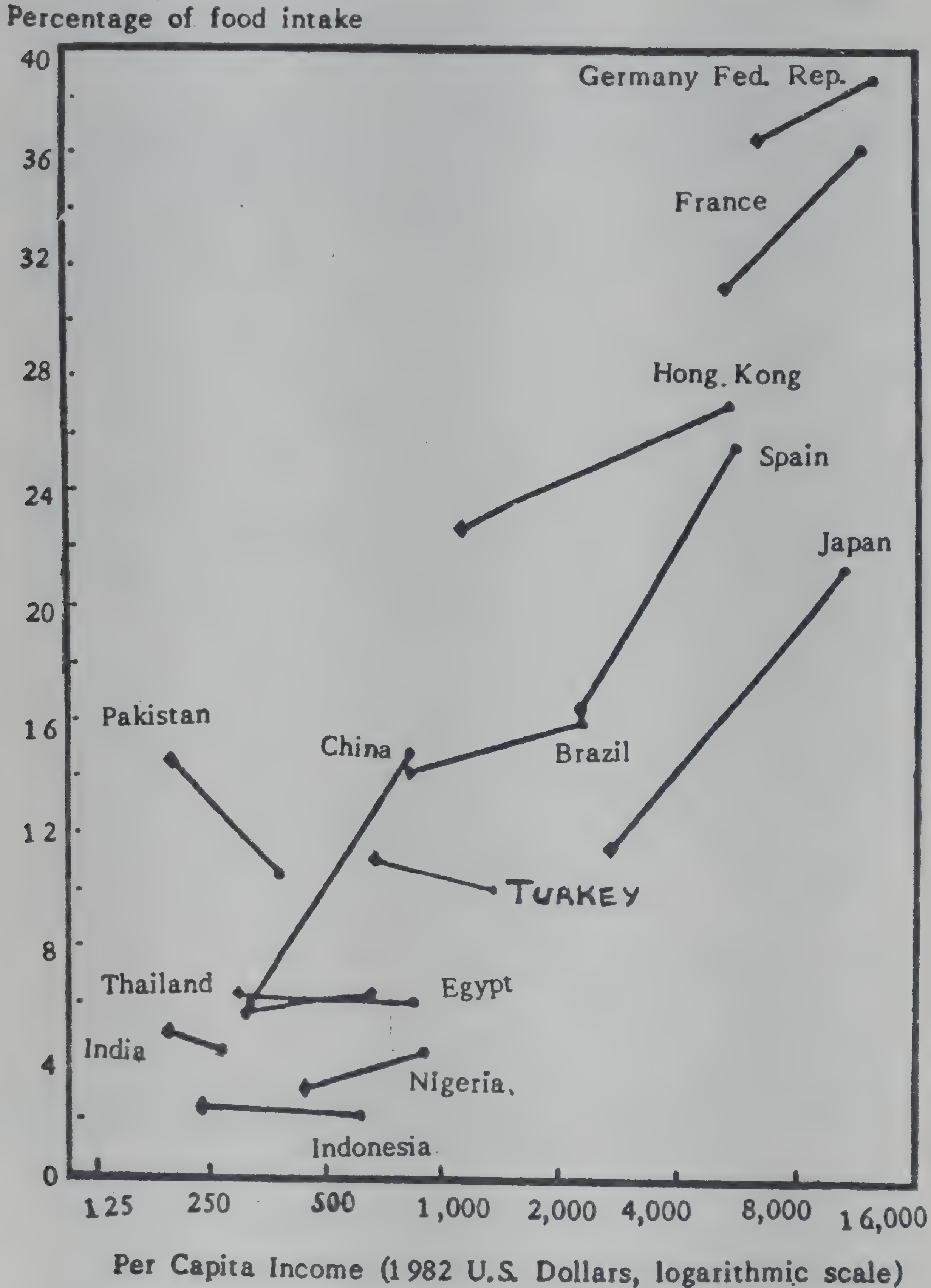

- Relationship in about 1960
- Relationship in about 1980
- QUADRUPLE projection 2000

Source : China, Long Term Development Issues and Options, A World Bank Country Economic Report, pp. 51 & 52.

with the increase in income levels. Based on these understandings and insights, the per capita food consumption in the case of India around the middle of the 21st century could be 3000 calories. Similarly, the share of animal products in total food consumption in the country could raise from a level of around 6 per cent to about 16 per cent in the year 2050. However, having regard to the general physical standards and the socio-cultural perception of the Indian population about non-vegetarian food, it may be safer to assume lower animal product share in food at about 12 per cent daily food intake of 2900 calories equivalent. Estimates for additional foodgrain demand in the year 2050 could be worked out relative to each of these parameters. Based on these assumptions, an indicative foodgrain demand for 2050 could be anticipated at around 550 million tonnes.

Table 2: Changing parameters of food demand and resultant additional foodgrain requirements for 2050

Parameters	Assumptions		Percentage change	Additional demand in 2050 (million tonnes)	Progressive total (million tonnes)
	2000	2050			
Demand level in 2000					235
Population (million)	950	1400	+ 47%	235 × 0.47=110	345
Daily caloric intake	2250	2900	+ 29%	345 × 0.29=100	445
Share of animal product in total food* (million tonnes)	6 (26.7) MTS	12 (53.4) MTS	+ 100	26.7 × 3.5= 93	538

* Increase in animal product consumption from 6% of total diet to 12% would lead to animal product consumption of 26.7 million tonnes i.e. 12% of 445 MTS. According to F.A.O. (The State of Food and Agriculture 1982, p.105) the average input-output ratio for the whole livestock system is estimated at 4.5 tonnes grain for one tonne of meat. Thus, additional foodgrain requirements for 26.7 million tonnes of animal product would be 93 MTS.

Manageable challenge. In absolute terms the demand projection of 550 MTS looks very formidable but in terms of Annual Growth Rates the challenge is manageable. It could be reached with an annual foodgrain growth rate of 3 per cent till the turn of the century and an average of 1.7 per cent thereafter in the next 50 years, with a gradual slowing down from 3 to 1 per cent. A possible realistic foodgrain production growth path has been worked out in Table 3. During this period, area under foodgrains production will reduce permitting diversion of land from foodgrain production to grass lands and/or raising other cash crops including, fruits, vegeta-

Table 3 : Likely growth path for 21st century

Period	Annual growth rate (Percentage)	Production at the end of the period (million tonnes)
1990	—	175
1990 – 2000	3	235
2000 – 2010	2.5	300
2010 – 2025	2.0	403
2025 – 2040	1.5	503
2040 – 2050	1.0	555

An alternate path of 3% annual growth between 1985-2010; 2.5% during 2010-2030 and 2% during 2030-2050 could give a production potential of 760 mts by 2050.

bles, oilseeds, *etc*., and to meet the land needs of growing urban settlements. Foodgrain productivity of land will have to be fairly higher than the growth rates indicated in this Table.

Between 1951–83 foodgrain production in India has increased at an annual rate of 3.3 per cent; from 51 MTS to 153 million tonnes. The indicated trend line production for 21st century is thus possible, sustainable, and also not optimistic.

Table 4 : Cereal yields in select countries

Country	All cereal yields (tonnes) per hect. of harvested area	
	1969–71	1979–81
United States	3.50	4.20
Netherlands	4.02	5.69
Japan	5.04	5.27
Egypt	3.85	4.01
Bangladesh	1.66	1.96
India	1.11	1.34
Korea, Republic of	3.50	4.77
Pakistan	1.21	1.61
Argentina	1.71	2.20
Mexico	1.52	2.11

Source : World Development Report 1984; p. 94.

There is yet another way to examine the production possibility: the wide potential for increasing foodgrain yields in India per unit of land. Currently, the per hectare foodgrain yield in India is estimated at around 1.3 tonnes compared to more than 5 tonne level recorded by some of the developed countries. Raising productivity to these boundaries of production potential could itself result in a production of nearly 700 million tonnes or more from the present area under foodgrain production. According to some estimates, lands in Gangetic plains in India hold the potential to grow crops sufficient for three-fourths of India's population[4]. Thus, given the right set of policies, a bold research effort geared to neutralise the resource constraints and to exploit the resource endowments, it should be possible for supplies to exceed demand. Section III deals with the supply side issues, which need attention to reach the expected levels of production.

III

Supply side issues

Agricultural success flows from a combination of soil, water and energy in many different ways. The role of science and technology in discovering new farming methods is crucial for increasing agricultural producion. The task of adapting these discoveries to the circumstances of the local conditions; disseminating results and encouraging farmers to adopt and providing back-up services needed for practising new technology, are some of the policy issues which need to be identified for early action. To start with, one may examine the situation in regard to land and water, the two basic resources for agricultural production.

Shrinking croplands. Increases in agricultural output, till about mid 60's, mainly resulted from expanding land under cultivation. Land is an inelastic resource and we seem to have, perhaps, already gone beyond the limits of arable land by cultivating even marginal lands and fragile hill-side slopes. A realisation is growing that this excessive land use for crop husbandry is causing an imbalance in the eco-support system for crop production as evidenced by reduced forest-cover, increasing incidence of floods and receding water tables. All these affect the yields of cultivated lands. Net sown area has not increased since 1971. In fact, the area of croplands may actually reduce from the present 140 m.ha. to 120-125 m.ha. as population in urban habitats expands relentlessly. This is borne out by the evidence of cropland trends in developed economies and the Chinese experience: Croplands decline as the countries industrialise and progress.

Land prices in the metropolitan and larger cities are already sky rocketing. Extension of *abadi* land (land reserved for habitat in settlement) is the single most important demand in majority of the villages. Fifteen per cent larger villages may acquire characteristics of towns in the process of trans-

Table 5: Select countries with declining cropland area

Countr	Postwar Peak in Arable Land Area (year)	Decline from Peak Year to 1980 (per cent)
China	1963	– 5.1
France	1960	–13.3
Hungary	1955	– 6.6
Ireland	1960	–29.4
Italy	1955	– 4.8
Japan	1960	–19.6
Netherlands	1955	–18.0
Poland	1955	– 9.7
Portugal	1963	–18.1
South Korea	1968	– 5.3
Sweden	1955	–21.0
West Germany	1955	–13.9
Yugoslavia	1960	– 5.6

Extracted from State of the World, 1985; p.25.

formation. Extension and expansion of urban settlements will swallow agricultural lands.

The urban population is projected to rise by about 150 million between 1981-2001. It is estimated that additional 6 million hectares of land may have to be diverted to non-agricultural purposes by the year 2000[5]. It implies that per capita increase in urban population needs about 40 sq. metres for settlement and support purposes, including roads, railways and water carrier system, *etc*. Working on this assumption, a projected increase in urban population of about 800 million by 2050 would need an additional 32 m.ha. one-half of this land may be wasteland and forest land. A conservative estimate may be that nearly 10 per cent of present agricultural land or around 14-16 million hectares of arable land may get reduced, thus leaving 125 m.ha. for net cultivation. Expanding croplands, therefore, is no longer a viable policy option.

Already the per capita availability of land in India has been reduced to 0.43 ha. per capita in 1986 from a level of 0.95 ha. in 1951. It is projected to be 0.34 ha. in 2000 and 0.24 ha per capita in 2050. The per capita availability of land will continue to shrink rendering millions of rural people to a

status of landlessness. Future increases in foodgrain production must, therefore, come from increasing productivity per unit of land through intensive agriculture and mixed farming including animal husbandry, poultry, piggeries, fish farming, *etc*. The hope for better quality of life for the 40 per cent or over 250 million rural poor is intimately connected with per capita productivity increases of farm workers. Raising per unit productivity of farmland and farm worker is the research challenge for the 21st century.

Raising productivity of land. There are three major determinants of agriculture productivity. All these must be simultaneoulsy present and in appropriate balance to raise productivity:

- New Technologies;
- Economic Incentives; and
- Input availability.

Agriculture scientist community in India has done a remarkable job in evolving a high-yielding seed-fertilisers-pesticide technology package for enhancing cereal productivity in the irrigated areas. It has transformed the country from a 10 per cent deficit food economy in 50's to a level of self-sufficiency in food. There is no doubt that our researchers will exploit the opportunities offered by emerging areas like bio-technology, genetic engineering, photosynthesis, tissue culture, bio-insecticides and pheromones for aiding the growth of agricultural productivity. Research organisations are the store house of knowledge but higher production would need that this knowledge is wrapped in technology packages for on-farm use. It will need an efficient extension system to transfer the new technology to nearly 100 million farm families, majority of whom are illiterate and, unlike their counterparts in developed countries do not have access to multi-channel TV, home computer services and experts at nodal points. For carrying the lab-to-farm messages, the knowledge base and communication skills of the extension agency would need to be greatly enhanced if the process of marketing of new technologies has to succeed. Research must, therefore, focus on these aspects.

Economic incentives. Farmers adopt new technologies only when they perceive definite financial gains in new methods of cultivation. The research organisations must, therefore, carefully examine the cost-benefit aspects of the new technology before it is commended to extension agency. Extension agencies, in turn, must satisfy themselves that new package of practices will result in necessary financial gains to the farmers who adopt new technology. However high the production possibility, there will be no takers if there are little economic incentives.

It may be relevant to share author's experience in promoting soyabean crop in the state of Madhya Pradesh (MP) to illustrate how economic incentives motivate farmers even to raise new crops when they perceive income gains.

For centuries, soyabean has been a higly valued and widely cultivated crop in many parts of the world, especially in China. It has very high protein content, and lends itself to processing into a variety of products of food consumption. Hoewver, there was hardly any soyabean cultivation in India before 1970. Recognising the market potential of this versatile crop and the economic gains which the farmers may get by raising this crop under favourable soil and climatic conditions, the author, as Director of Agriculture in the state of Madhya Pradesh (M.P.), initiated a programme for popularising soyabean cultivation. Demonstration plots for raising soyabean were laid on 5000 hectares of land in the kharif season of 1971. Encouraged by the results of these demonstrations, a high pitched extension campaign was launched highlighting the financial benefit and economic gains received by soyabean cultivators: "*Ek Roopye Ke Do Roopye*" 'Two rupees worth crop for investment of one rupee" was the slogan. The idea caught up and this crop is now planted in M.P. over an area of 1.3 million hectares.

There are large areas in the Malwa and adjoining regions in M.P. with deep black cotton soil and high rainfall in the monsoon. These soil and climatic conditions make it difficult for the farmers to cultivate this potentially productive land in kharif or monsoon season with high-value crops. Mostly the cropping pattern was either jowar or maize in kharif or wheat in rabi. Yields in both cases were low. Researchers from the Illinois University, who were working with the State Agricultural University, based on the research results of university field experiments, recommended that soya cultivation will be profitable for this region. Soya is a short duration kharif crop; it could be harvested in time to enable wheat planting in rabi on the same plot of land. Further more, the leguminous character of soyabean helps soya-wheat cropping rotation. No soyabean cultivation was ever done in M.P. and, therefore, the farmers expressed their apprehension about undertaking cultivation of a crop for which there was no visible market. It was decided to offer a guaranteed market price of about Rs. 75 per quintal in the year 1971 and also to advertise market potential of the crop and its processing prospects. This gave confidence to farmers to experiment with soyabean cultivation. The farmers immediately perceived the economic gains and soyabean cultivation has expanded rapidly in M.P. from a level of about 5,000 hectares in kharif 1971 to 1,319 thousand hectares in 1987. The productivity levels have also increased from about 4.4 quintals per hectare in 1972 to 7.6 quintals per hectare in 1985. This soyabean expansion programme has also helped to establish more than 20 soya processing plants in the region. In a way, it has revolutionised the local agricultural economy. Farmers have become richer. Low value crops have been replaced by high value soyabean. This year soyabean is reported to have been sold at more than Rs.400 a quintal, thus adding an additional crop valued at more than Rs. 600 crores. Processed soya oil is a welcome addition to the country's edible-oil deficit economy. Soya-meal has

emerged as an important export earner. A few processed soya-meal consumer products are already in the market and plans for expanding down-the-line soya-meal processing industries are on hand. M.P. is regarded as a backward state but the farmers saw a window of opportunity, and responded handsomely once they perceived 'income gains' of the new soya cultivation technology.

Table 6 : Soyabean expansion in Madhya Pradesh

Year	Area in thousand hectares	Production in thousand tonnes	Productivity: quintal/ hectares
1973	13.4	5.9	4.4
1978	198.6	86.8	4.4
1983	613.8	461.6	7.5
1985	1096.[illegible]	829.0	7.6
1987	1319.4	Not yet available	

Source : Information provided by Director of Land Records, M.P.

It is a little surprising that even while the potential of soyabean in M.P. has been established, soya area has not expanded much in other states. M.P. constituted over 90 per cent of 1.3 m.ha. soyabean area of the country in 1986. A detailed review of soyabean development programme in the state brings out some important lessons for raising productivity of land and popularising new agriculture technology:

(*a*) Appropriate crops must be identified to suit the local soil and agro-climatic conditions;

(*b*) Cost-benefit analysis should be carefully made and economic benefits for individual farmers from such new practices must be highlighted in inter-personal extension messages and through multi-media channels;

(*c*) Market interest in the new opportunities should be promoted by disseminating information about the economic value, market potential and crop related trading and processing facilities. Trading community, perceiving gains for itself, become motivators and influential allies for extension;

(*d*) Projectised approach for the extension agency must be worked out in meticulous details in regard to organising supply of inputs and credit, demonstrations and contact with farmers; and finally,

(*e*) Market arrangements for purchases at guaranteed support prices at the very initial stage and strong research support was vital to the success of soya cultivation in the state. Except for the first few

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years, hardly much soyabean was procured by state agencies at support price.

Similar approaches supported by detailed projects could help better land-use and higher productivity in regard to other crops and in other parts of the country which are professedly more progressive than the state of M.P. Search for identifying plants and trees which could be raised on waste and marginal lands offers a potential window of opportunity. Fruit trees could also be planted on these lands under responsibility system and this could create wage employment for the poor.

Credit and Marketing Support System. Application of new technology always involves use of diversified inputs and greater investments. An efficient marketing and responsive credit system is most essential for wide scale application of new technologies. Marketing system can become a major constraint in the next century when the country transforms from rural to a predominantly urban society. Presently, nearly 70 per cent of the agricultural production is consumed by the producers. In the year 2050, when the rural population will constitute hardly 15-20 per cent of the total population of the country, major part of the production will have to move to the consuming centres through marketing channels. A very large proportion may be processed food. Research must, therefore, be geared to examine the future problem of marketing, transporting, warehousing, processing and finally reaching the consumers. This is an area of research which has not received adequate attention.

Our pre-occupation with crop production has accorded a low priority to animal husbandry and fisheries development. Changing food habits in favour of animal products and fish has been referred to in the earlier section. Greater research efforts for animal husbandry, poultry and fish farming need to be initiated. Processing and marketing of these commodities is another area of concern. Corner meat shop marketing system will no longer suffice. Processing, packaging and efficient delivery system at distant consuming centres is a pre-requisite for the success of production effort in this area. We have the benefit of the highly successsful Anand model of dairying and milk marketing in cooperative sector and some efficient large-scale dairying milk processing private enterprises. A suitable varient of these models could succeed in the marketing and processing of other animal products. Some pioneering organisational efforts in this direction need to be initiated early.

Mechanisation or raising productivity of farm workers. In the developed regions, mechanisation helped cropland expansion and intensive agriculture leading to productivity increases. Agriculture in India is still predominantly dependent upon human and animal energy. This situation may continue for another two decades, as the rural population is projected to increase by another 100 million by the turn of this century. However, this

phenomenon is likely to reverse in the first decade of the 21st century and the rural population may decline by about 5-10 million in the first decade. Urbanisation will continue to gather momentum. Experience of rural-urban demographic shift in developed countries suggests that India's urban population may constitute about 80 per cent of the total population by 2050; rural population perhaps declining to less than 280 million from a high level of about 650 million in 2000. This structural shift has serious research and policy implications for mechanisation of Indian agriculture. In the immediate future, researcher may focus on designing implements which enhance productivity of human labour without lowering labour intensity in agriculture and thereafter they should be ready to introduce sophisticated farm machinery. Industrial process and plants can be purchased and installed. In the case of agriculture, even machines, to prove useful, will have to be shaped and adapted to suit the local soil and climatic conditions. Research in farm machinery must be intensified at two levels. First, in the area of hand tools and animal driven machines for next 15-20 years and; simultaneously, research must also start for designing and adapting sophisticated machines to meet the requirements of the 21st century. Without this advance action we may not be able to cultivate efficiently and this may adversely affect agricultural growth rates in the 21st century.

Raising per unit productivity of water. Next to land, water is the most important factor of agriculture production. Availability of moisture at the right time in right quantities determines the productivity of agriculture. Since mid 60's, agriculture productivity increases are mostly accounted for by application of fertilisers — insecticide package, high-yielding variety of seeds in irrigated land. It is estimated that irrigated land constituting 30 per cent of cropland contributed 57 per cent of the foodgrain production. Irrigated agriculture is, thus, nearly three times more efficient than unirrigated agriculture. Further, irrigation helps increase the harvested area. Gross sown area increases as irrigation expands: harvested area has increased to 180 million hectare in 1983 from 165 m.ha. in 1970. Net sown area remained unchanged at about 140 m.ha. However, there was substantial increase of 21 m. ha. in irrigated area increasing from 38 to about 59 m.ha. This has resulted in multicropping, intensive agriculture and enhanced employment potential. Labour migration from Bihar and Eastern U.P. to Punjab for agricultural operations is a good illustration of greater employment generation and expanding irrigation co-relation. In Punjab, 80 per cent of the total area is irrigated compared to an All India average of 30 per cent.

Water is a limited resource. As against the present irrigated area of about 60 m.ha. the ultimate potential for irrigation has been assessed at 114 m.ha.

Table 7 : Irrigation potential and utilisation *(in million hectares)*

	Ultimate potential	Potential created (1984-85)	Utilisation
Major & medium surface water	59	31	25
Minor surface water	15	10	9
Ground water	40	28	26
Total	114	69	60

Source : Seventh Five-year Plan 1985-90, Vol.II, p. 72.

The Planning Commission has also projected that 50 per cent of cultivated area will remain dependent on rainfall even after full irrigation potential is exploited. These are assumptions which need to be seriously examined by scientists and researchers. We also need to investigate whether there are no better methods and technology for increasing per unit water productivity and thereby saving water and making it available for additional areas. There are some distinct possibilities. An irrigation system, which inspires confidence amongst farmers that water would be delivered at farm-gate when needed, is a simple innovation which can reduce water withdrawls.

As Commissioner of Raipur Division (Madhya Pradesh), the author had the privilege of conducting an elementary experiment with regulated irrigation supply for paddy crop in a plot of nearly 100 acres. This region normally gets over 45″ of rain. Paddy is the main kharif crop. Mahanadi irrigation system, irrigating over three lakh acres, is protective in nature: irrigation water is supplied only when there are gaps between rainy spells or at the time of maturity which is a period of moisture stress. 1979 was a drought year and water level in the reservoirs was low and irrigation demand high. This was an inspiration for setting up an experiment with the help of agriculture and irrigation agencies to examine whether there was any easy-to-practise technology to maintain productivity while using lesser quantities of water. Pucca field channels were made for a 100 acre experimental plot with provision for irrigation water supply at the farm gate. Moisture stress was reported by farmers and/or agriculture experts. This permitted wet conditions in the farm but not the knee-deep water which is usually stored in the paddy fields of Chattisgarh where field-to-field flood irrigation system is a common norn. A plot of nearly 100 acres followed old established practice and received 22-24″ irrigation water compared to 14″ which was supplied to the experimental plot during the paddy season. Demonstration plot yielded an average 22 quintal of paddy per hectare compared to

15 quintal in the controlled plot. Inference is obvious. Productivity per unit of water can be increased. Water withdrawals can be reduced by scheduling irrigation according to weather conditions and moisture needs of the crops. The very next year this programme generated great interest and demand. According to information the programme has made some steady progress.

In Nebraska (USA) farmers can approach the Institute of Agriculture and Natural Resources for advice on telephone hot line regarding scheduling irrigation for their crops. The Centre's response is based on computer processed data by a programme rightly called 'IRRIGATE'. It reduces total water needs. Similarly, Israel has developed an automated irrigation system in which the time and amount of water is controlled by computers. It is estimated that as a result of sprinkler irrigation and drip-system of irrigation combined with optimum irrigation practices, there was a 20 per cent saving in water per hectare between 1967-81. Irrigation area expanded by 39 per cent while irrigation water withdrawals rose by 13 per cent[7].

In the present situation we may not be in a position to introduce the above stated level of sophistication: investments needed may be prohibitive or our farmers may not be in a position to absorb and practise this technology. However, we certainly should analyse the prospects and possibilities through experimentation. Regulated water supply at farm-gate is immediately feasible. Major component of investment will be human labour and local raw material use. This fits in with our startegy of expanding wage employment through Public Works which create productive community assets. The real bottleneck which one foresees is the availability of adequately trained manpower in civil/agriculture engineering cadres and the matching component of agronomists who can generate confidence amongst farmers and who operate the regulated water supply system in a responsive manner. This impediment could be overcome through training of higher secondary qualified young students through one year specially tailored certificate course. Anticipated gains may far outweigh the investments. For educating farmers, we may follow Community Information and Planning System (CIPS) approach. Irrigation beneficiary/community groups may be organised and involved right at the data collection stage for planning low water use high agriculture productivity practises; community should be sensitised about scarcity value of water while analysing data. A local group should organise implementation and operation of the system with the assistance of skilled workers providing expert advice and help. It may be a slow process to begin with but ultimately results may be most remarkable.

Hydraulic engineers seem to be preoccupied with water storage reservoir and main canal construction works. Agricultural scientists seem to be more concerned in increasing productivity per unit of land for irrigated and rain-fed lands. Nobody seems to be investigating possiblities for increasing irrigation potential from available storage. Research projects which focus

on exploring ways of raising per unit productivity of water is the most urgent and priority area for research. Perhaps, new centres of research manned by scientists with relevant training and outlook may have to be established. Alternatively, the existing research institutions could be reorganised with specific mandate to focus on issues relating to raising productivity of agriculture per unit of water. Sensitisation of extension and research agencies at all levels to the scarcity value of water will be crucial to the success of such a programme. Agriculture University and agriculture extension agency linkage model, may be tried. Credibility and confidence of farmers could be earned fairly quickly through field demonstration provided the technology is right and benefits to farmers or community could be convincingly demonstrated.

Increasing Usable Potential of Water Resource. There is yet another equally important aspect which needs attention: Increasing usable potential of water resource. Water is a solar-powered renewable resource. Sun energy lifts water from the earth's surface and an equal amount falls back to earth in the form of rain, snow and sleet. Fortunately, 54 per cent more water falls on land than annual evaporation. Globally, land receives 110,000 cubic kilometres of water compared to yearly evaporation of 71,500 cu.km. The comparative estimates for India are not readily available. The volume of total run-off is, however, known. In terms of per capita run-off, India would occupy a middle place (Table 8).

Table 8: Average annual per capita run-of
(thousand cubic metres run-off)

Country	1983	2000
U.S.A.	10.0	8.8
Indonesia	9.7	7.6
France	4.3	4.1
Nigeria	3.1	1.8
China	2.8	2.3
India	2.1	1.6
West Germany	1.4	1.4
Bangladesh	1.3	0.9
Egypt	0.09	0.06

Source: State of the World Report, 1985, p. 45.

Based on the above data the estimated total annual run-off for India could be of the order of 1533 million cu. metre per annum or ignoring seasonal fluctuations, 4200 billion litres per day.

Water is a factor of production in agriculture, industry and household activities. As the country modernises and develops, requirement of water for industry and civic uses increases and also inter-sectoral pattern of consumption alters greatly (Table 9).

Table 9 : Estimated water use in select countries, total, per capita, and by sector 1980

Country	Daily water withdrawal		Share withdrawn by major sector		
	Total	Per capita	Agriculture	Industrial	Municipal
	(billion litres)	(thousand litres)		Per cent (in litres per day)	
United States	1,683	7.2	34 (2448)	57 (4104)	9 (648)
Japan	306	2.6	29 (754)	61 (1586)	10 (260)
Mexico	149	2.0	88 (1760)	7 (140)	5 (100)
India	1,058	1.5	92 (1380)	2 (30)	6 (90)
United Kingdom	78	1.4	1 (14)	85 (1190)	14 (196)
Poland	46	1.3	21 (273)	62 (806)	17 (221)
China	1,260	1.2	87 (1044)	7 (84)	6 (72)

Source : State of the World Report, 1985, p. 49.

India's water use pattern in 2050 may not be the same as that of U.S. but there is no doubt that water use pattern would have undergone a radical change both qualitatively and quantitatively as a result of vastly different structures of production and life style in 2050. Long-term time series, cross section, trend-line data are not available for analysis and forecasting. Based on the information available in Tables 8 and 9, it may be reasonable to speculate that daily water use needs for industry may reach nearer to 50 per cent of Japanese level (1586 litres) or around the present level of Poland (806 litres per capita per day).

Because India is a warm country, civic needs will tend to be high as life styles improve. It may be reasonable to assume that civic needs of water

will more than double by the middle of next century. It could be nearly 200 litres per capita per day.

Increase in irrigation water use may be less than twice the present consumption level, projected daily average demand could be 1600/1700 billion litres (BLs) compared to 973 at present. Presently about 60 m.ha. is under irrigation and accounts for 973 BLs of water per day/(92% of 1058 BLs). The maximum irrigation potential is estimated to be 110 m.ha. As such, the maximum demand for irrigation water may not exceed 83 per cent the present level or 1800 BLs per day. Making allowance for nearly 8-10 per cent saving in irrigation water use resulting from the relative increase in the percentage of ground water use, daily average demand for irrigation withdrawals could be projected at 1650 BLs per day on average. Based on this assumption, the following scenario emerges:

India : Daily water withdrawal per capita
(in litres)

	1980 (Estimates derived from Table 9)	2050 (Projected)
Industry	30	800
Civic use	90	200
Total	120	1000

The daily water withdrawal needs for industry and civic use for a population of 1400 million at the rate of 1000 litres per capita may amount to 1400 billion litres. Agriculture may account for an additional 1400 litres per capita per day. Total water drawal needs including agriculture work out to 3050 BLs. This may constitute 73 per cent of the total estimated annual run-off and a near three time increase over the present level of water availability. One wonders whether it is within the realm of feasibility to store and utilise such a high percentage of annual run-off. Future development in water use conservation technology for industrial,civic and agriculture purposes can reduce the actual water requirements by about 30%. One thing is, however, certain that it would need an herculean effort and a host of new approaches for generating such large quantities of water to match the emerging demand for a modernised developed society.

Augmenting water supplies. There is no single solution for augmenting dependable supplies of water. Constructing dams to store run-off has been a historical solutoin to the problem. Bigger and bigger dams have been constructed during the century. We are, however, fast running out of economically viable sites for surface dams. Some emerging possibilities for augmenting water supplies are:

(a) Managing micro watersheds to stabilize run-off and additionally avoiding soil loss and helping crop productivity.

(b) Afforestation and reforestation to reduce run-off to help percolation of water underground is already recognised as a preferred choice.

(c) Potential to store water underground through artificial recharging of acqulfers or by other means is another exciting possibility. It is reported that Israel transports annually 300 million cubic metres of water from north to south through its National Water Carrier System and stores two-thirds in its underground storage system. Such an approach avoids use of valuable land required for surface dams and would also prevent large evaporation losses. Soviet Scientist M.L. L'vovich considers that 21st century will undoubtedly be the century of underground water reservoirs[8].

(d) Use of underground water is largely being managed by farmers through private lifting devices. This reduces burden on public exchequer and ensures efficient use of water and higher productivity. Research support for increasing efficiency of lift irrigation should be a priority area of research for immediate future. This should be combined with an aggressive development communication effort at demonstrating efficient irrigation management techniques through mobile laboratories equipped to evaluate the relative efficiencies of different irrigation systems–gravity, sprinkler and drip and recommend the most cost effective irrigation system for the farmer.

(e) Pricing water at the marginal cost can greatly enhance efficiency of water use. This may not be politically and socially feasible at this stage. All the same having farmers pay some share of the rational percentage of irrigation costs will give them a stake in the system and improve water efficiency.

Conclusion

To sum up, it could be projected that foodgrain demand may reach a level of around 550 million tonnes in 2050. This level of achievement is both feasible and desirable. However, to reach this level of production from shrinking arable land declining from 140 to less than 125 m.ha., productivity per unit of land may have to be raised by a multiple of 4 or more. Development and application of science and technology which ensures income gains to farmers, mechanisation, strengthening of credit and marketing, processing and warehousing and transport and communications infrastructure, set the agenda for research issues for the next century. The system may collapse if fresh water supplies do not match demand. Research must, thus, accord

high priority to the issues relevant to efficient storage, conveyance and conservation of water. It may be reiterated that these projections are not forecasts. There are distant projections based on a set of assumptions, past trends and lessons from the happenings in the developed countries. These projections could be refined with better knowledge and insights as new evidence becomes available. It is intended to stimulate discussion for new policy initiatives in anticipation of a possible distant scenario.

Appendix

India is a low income country with a per capita income of $ 260 and the life style of the people is determined by this income level. Therefore, the food habits are likely to change drastically in the coming years. To estimate the food demands it is necessary to make certain projections. An attempt is made here to have these projections on the basis of overall trends and the specific experiences of some developed countries.

Projected income level by the year 2050

The following Table gives the trends in average annual growth rate by regions and for some selected countries:

Table 1

(per cent)

	1960–70	1970–82
Middle Income Economies:	6.0	5.4
Oil importers	6.3	6.0
Upper Middle Income	6.4	5.4
China	5.2	5.6
Pakistan	6.7	5.0
Korea	8.6	8.6
Brazil	5.4	7.6
Algeria	4.3	6.6
India	3.4	3.6

It can be seen that most of the middle income and upper middle income economies have recorded a growth rate of more than 5 per cent. In the case of India, GDP growth rate in 1960-80 period has been around 3.6 per cent. It is, however, now established that the Indian economy is on an upward growth path: annual average GDP growth rate during the Sixth Plan period is estimated at 5.1 per cent. The population growth rate during this period was around 2 per cent. Thus the annual increases in per capita income were of the order of 3 per cent per year. It can reasonably be estimated that the economy may continue to grow at about 5 per cent during 1984-2000 period and at a slightly higher rate during the subsequent time periods when the population growth rate is estimated to slow down from the present 2 per cent to a level of about 0.4 per cent by the year 2050. Based on these presumptions, the per capita income level in the year 2050 could be $ 3400. Table 2 could be a possible growth path.

Table 2 : Projection of increase in per capita income level up to the year 2050

	Growth rate in per capita income during the period (Percentage growth)	Per capita income at the end of the year of the period $ 1984	Remarks
(1)	(2)	(3)	(4)
1984 (Actual)	—	260	
1984 - 2000	3.1	425	Per capita growth level same as witnessed during the Sixth Plan.

Table: 2 (*Contd.*)

(1)	(2)	(3)	(4)
2000 – 2015	4.0	765	Population growth rate slows down but GDP grows at the current rate of 5 per cent
2015 – 2030	4.5	1480	Population on growth slows down further but GNP grows slightly at higher rate
2030 – 2050	4.5 4.0	3400	Both population growth and GNP growth rate slow down marginally

The above projections of growth of per capita income are fairly modest. Growth rate could be much higher if India were to follow the GNP growth path of middle income economies witnessed in the last two decades. In fact there is no reason that atleast in the 21st Century India's G.N.P. should not continue to grow at 5.5 per cent rate per year. For the past trends the Table below gives an idea as to how the annual growth rate of Indian economy has been accelerating in different time periods.

Table 3: Average annual growth rates of Indian economy in different time periods

Period	Growth rate (Per cent)
1950–65	3.7
1965-73	3.9
1974–80	4.4
1980–84	5.1

Approach paper for the Eighth Plan aims at 6 per cent growth of economy. If this optimistic trend could be maintained over the first half of 21st century, the per capita growth over the period could average around 5 per cent. In such a scenario the annual per capita income in 2050 AD could as well be over $ 4500.

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